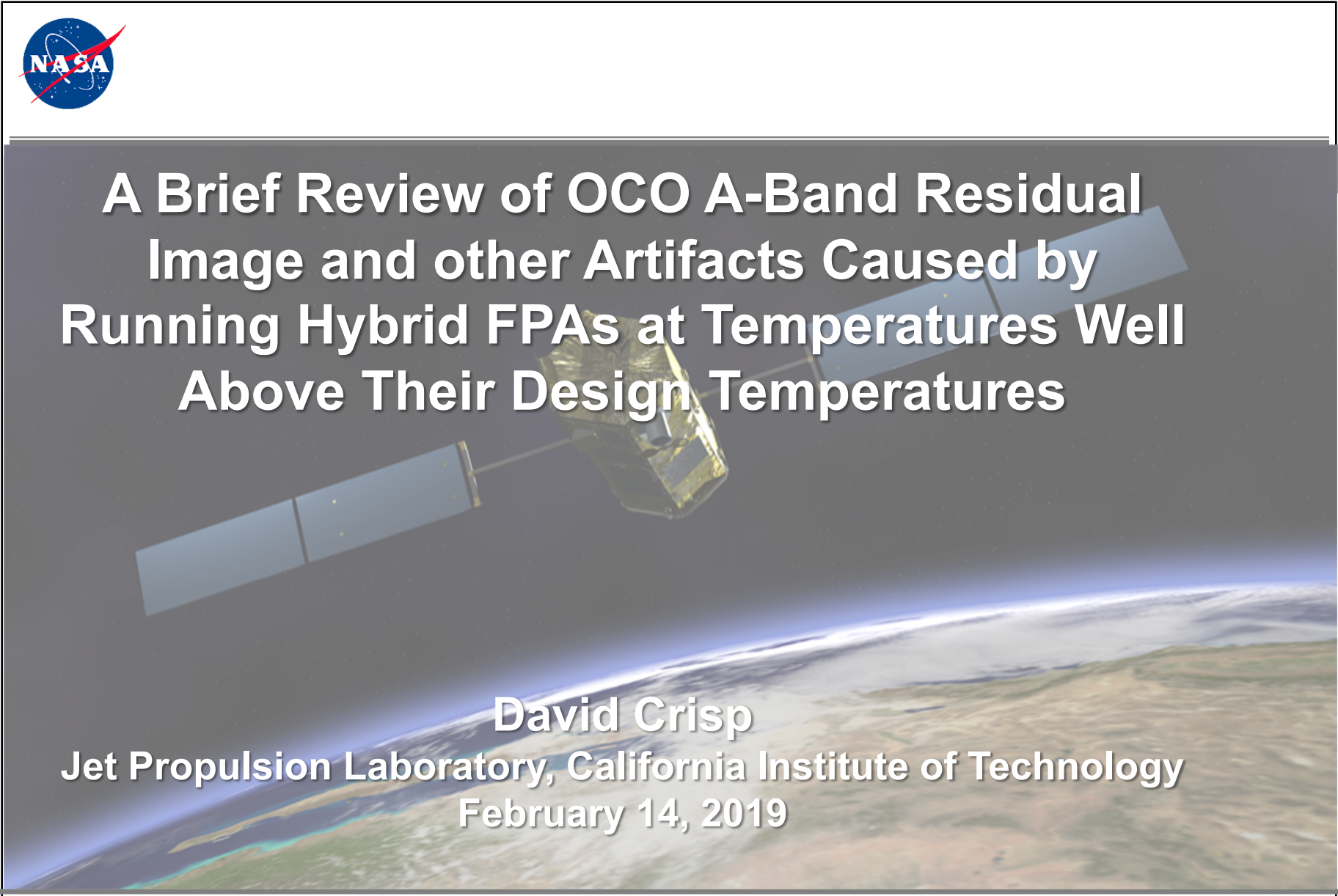

A Brief Review of OCO A-Band Residual Image and other Artifacts Caused by Running Hybrid FPAs at Temperatures Well Above Their Design Temperatures

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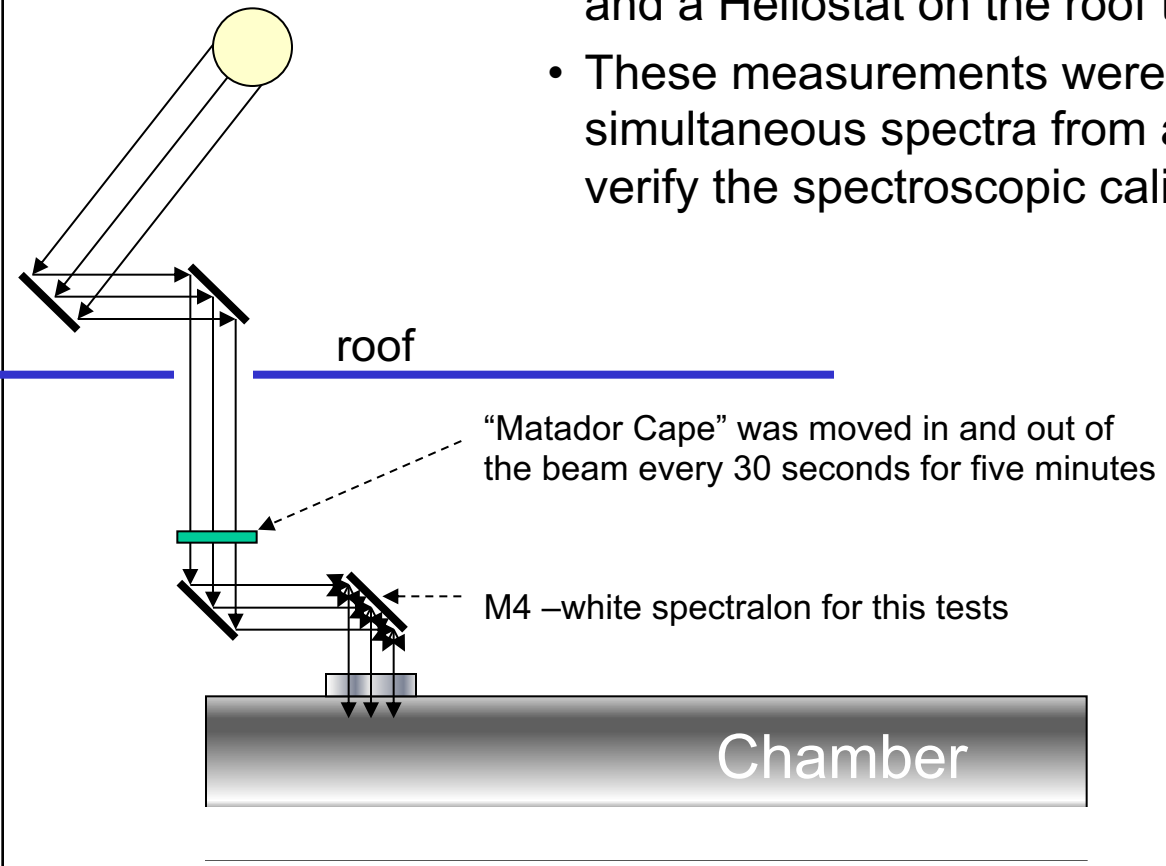
Residual Image

- On the original OCO instrument, the two HgCdTe FPAs used in the CO_2 channels were operated at 120 K, but the HyViSi used in the O_2 A-and channel was operated at 180 K
- Three FPAs have three very different personalities
  - 2.06 micron FPA performed as expected
  - 1.61 micron FPA exhibited residual image that was traced to poor conductor in the FPA/ROIC package
  - O2 A-Band had a slow response dependent upon the spectral content in the scene
    - Not seen with shuttered tests with white light and collimator
    - Seen with “Matador” tests with the heliostat, with strong spectral structure
- Prior to the OCO launch, the A-band residual image was thought to be
  - Intrinsic to this technology and this ROIC design
  - Associated with an interaction between interpixel capacitance and an unidentified capacitance in the circuit associated with each pixel
- While basically correct, this was only a partial explanation
- We later learned that the A-Band FPA operates normally, with no significant residual image ($< 10^{-4}$) when operated below 120 K

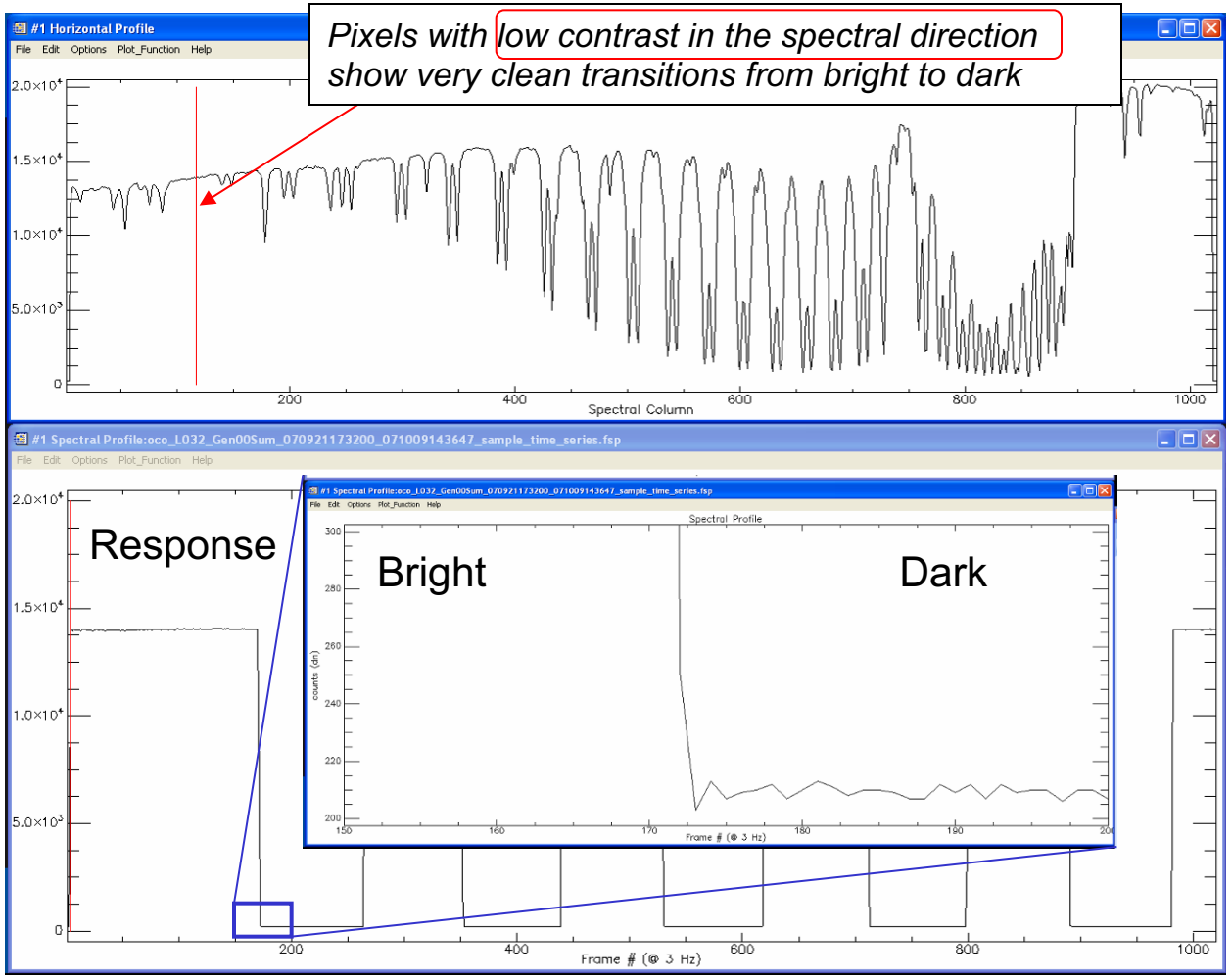
A Quick Review of the A-Band Residual Image

- During the pre-launch thermo-vacuum (TV) tests, the flight instrument could view the sun through a window and a Heliostat on the roof the building.
- These measurements were compared with simultaneous spectra from a nearby TCCON station verify the spectroscopic calibration



In the "Matador tests", the light was chopped with a metal shutter to test the temporal response of the focal planes and to characterize residual image

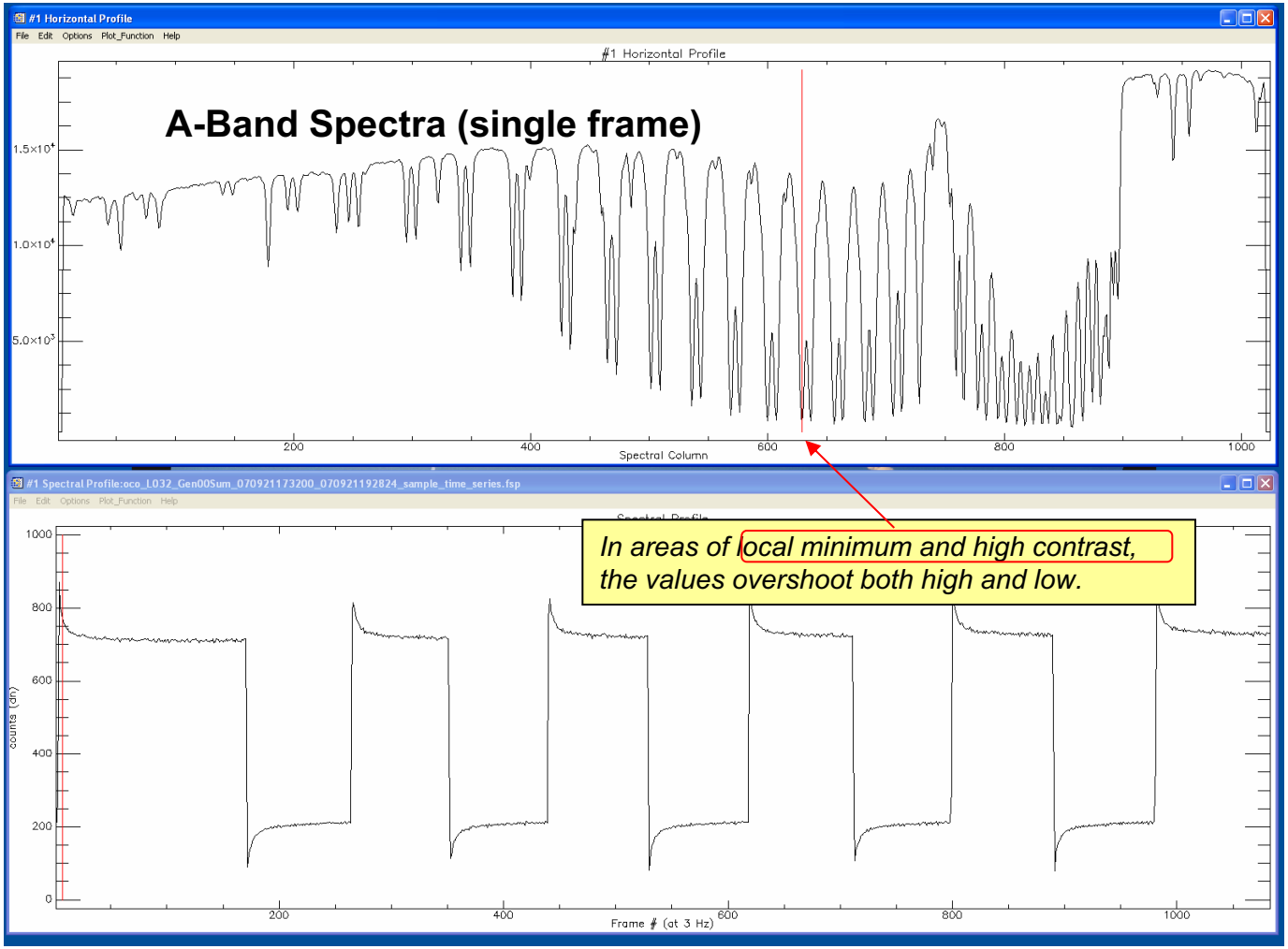
4 O_2 A-Band 5-Second Residual Image Continuum Behavior



The A-band HyViSi Response

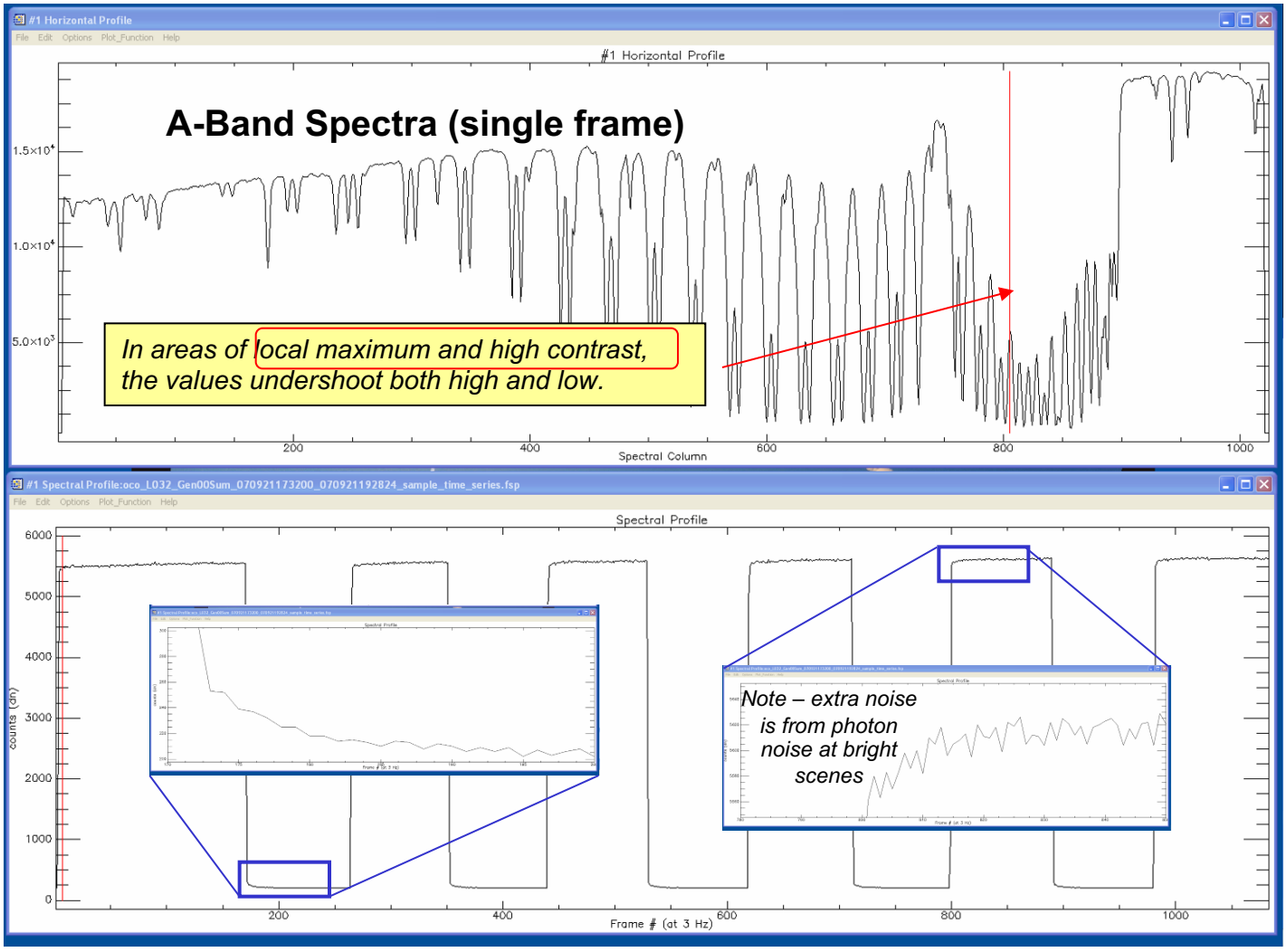
In regions with little spectral contrast, the FP responded correctly, transitioning from bright to dark within ~1 exposure (0.333 sec)

A-Band Residual Image
Local Minimum w/Large Positive Second Derivative



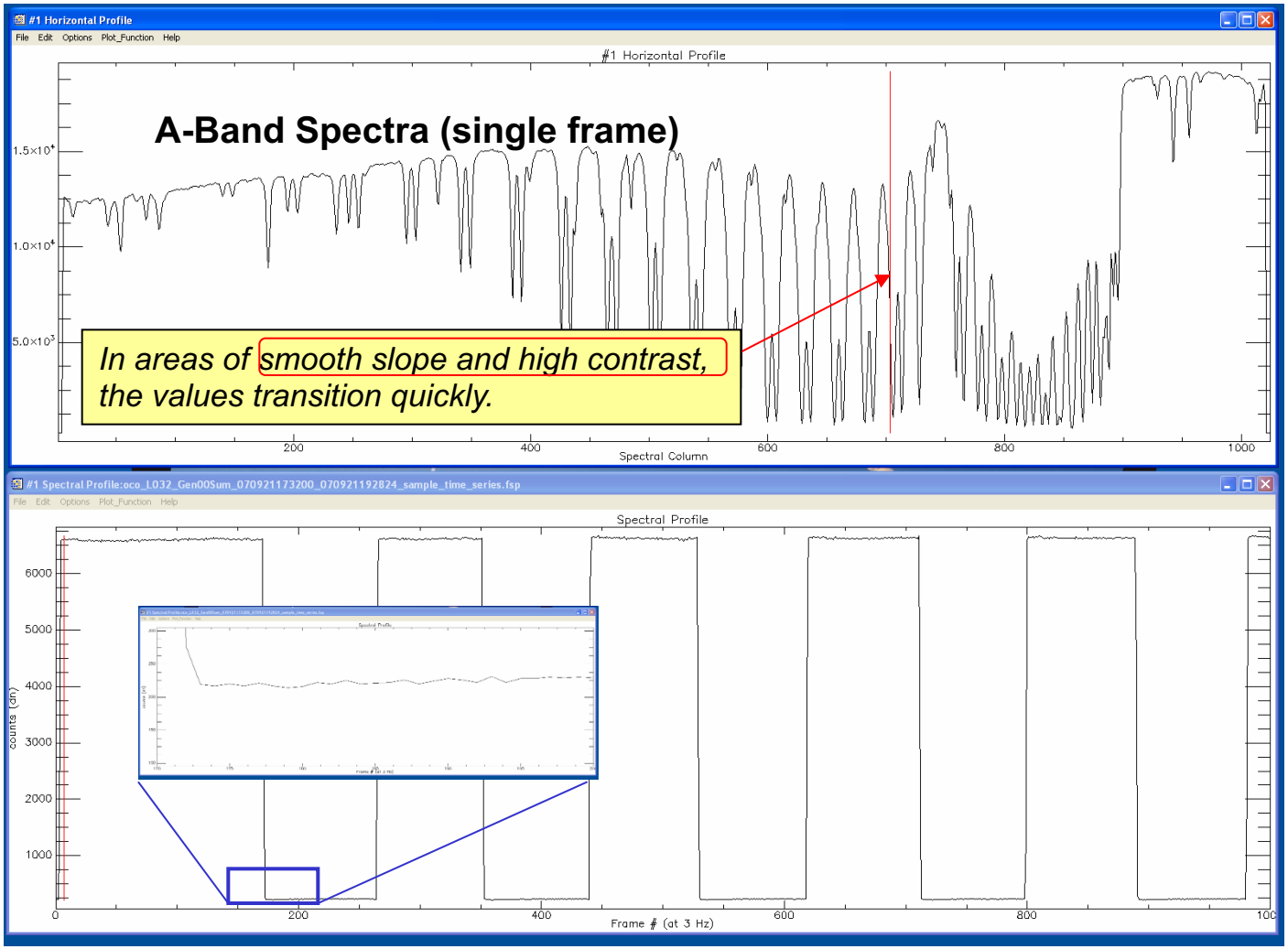
In spectral samples at wavelengths near the core of spectral lines (local minima), where the intensity increases on both sides of the sample, the FPA response overshoots transitions from dark to bright or bight to dark, and requires several integration times to recover.

A-Band Residual Image
Local Maximum w/Large Negative Second Derivative



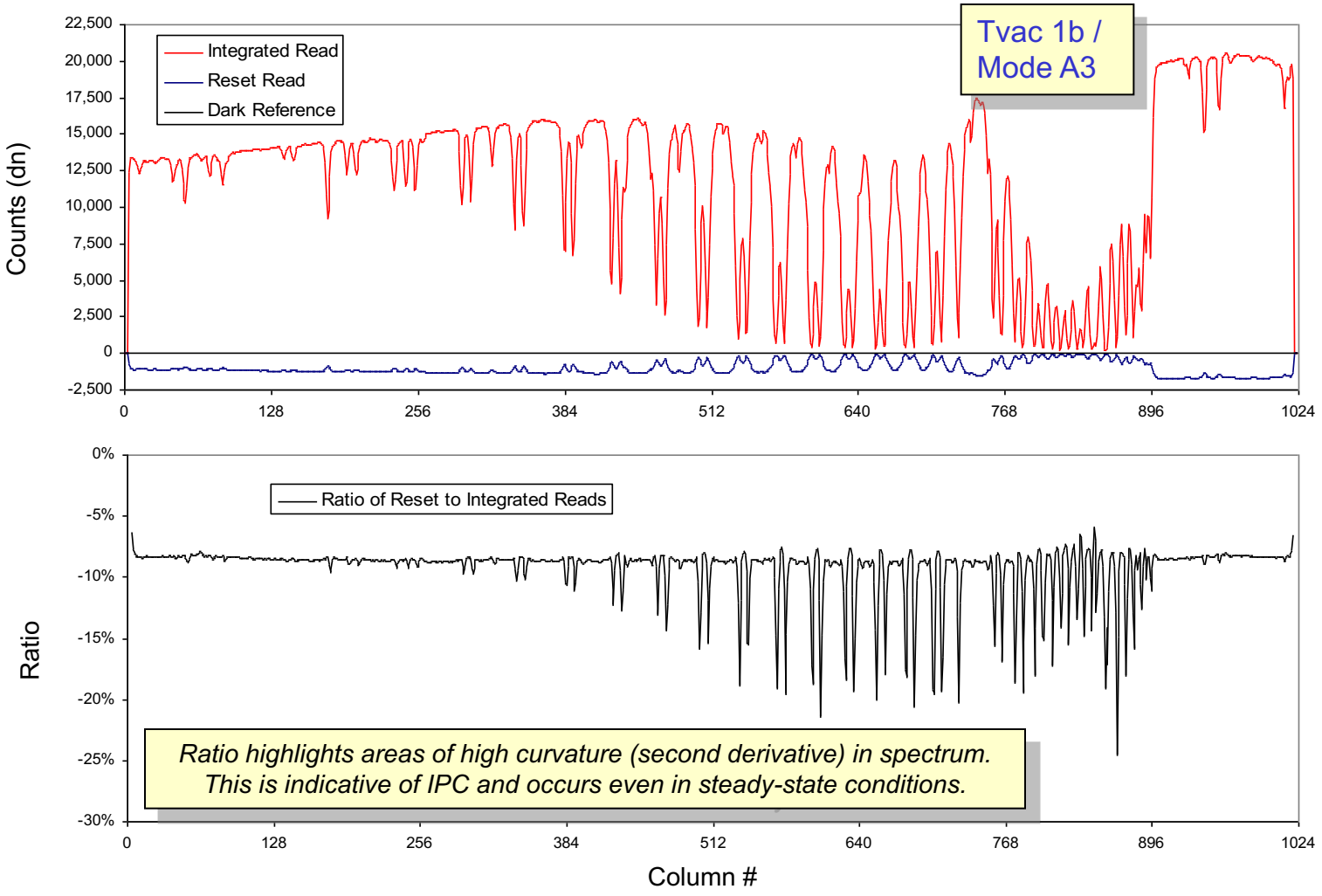
In spectral samples near local maxima, where the intensity decreases on both sides of the sample, the FPA response undershoots transitions from dark to bright or bight to dark, and requires several integration times to recover.

A-Band Residual Image
High First Derivative, Low Second Derivative



In spectral samples where the intensity increases or decreases uniformly, the FPA response returns to normal.

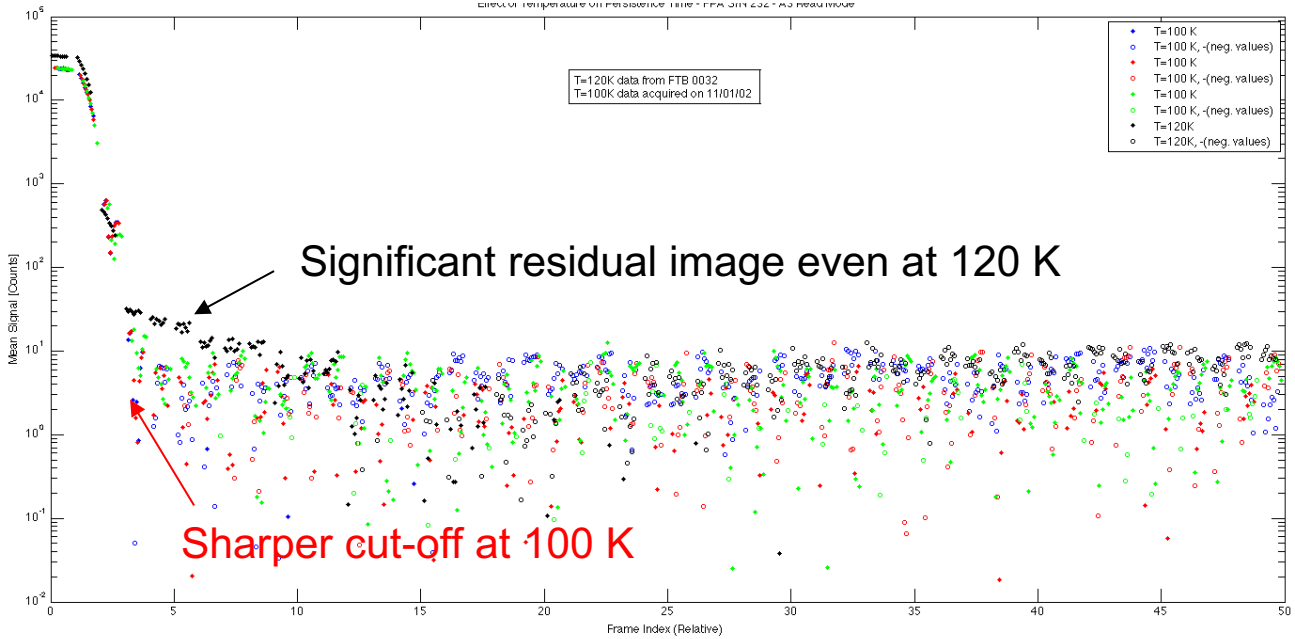
#3 A-Band FPA Errors in the Areas of High Spectral Content



The temporal response artifacts introduce complex errors in the spectrum (roughly proportional to the 2nd derivative of the intensity)

Pre-Flight FPA Testing for OCO-2

- During pre-flight testing of the OCO-2 FPAs, the residual image response of both the Si HyViSi and HgCdTe FPAs was measured as a function of temperature
  - FPAs were screened at 100, 120, 130, and 180K to screen for residual image
    - All of the first batch of substrate-removed HgCdTe FPAs produced residual image at T > 100 K
    - A few of the old OCO spare FPAs could be operated at temperatures as high as 120 K, so we used those in OCO-2



Frame index after Bright/Dark Transition

Response vs time (# of 0.333 sec frames) for HgCdTe FPA at 100 K (colored dots) and 120 K (black dots). At 120 K, this device required ~3 seconds (10 frames) longer to recover to the baseline seen at 100 K.

Additional Experience at ESA

- ESA explored the use of Teledyne FPAs for CarbonSat
- In this application, passive cooling was the only option, due to cost constraints
  - With passive cooling, the FPAs could only be cooled to 150-180 K
- Teledyne FPAs were being considered to provide the performance needed to meet the requirements
  - Based on thermal dark current alone, these FPAs could still meet the CarbonSat specs at temperatures a high as 180K
- I could not provide the details of JPL experience, due to ITAR restrictions, but suggested that this might not work, and suggested that they should run a test
- The CarbonSat team ran tests at temperatures near 180 K using Teledyne H2RG FPAs that JPL had supplied for the Euclid mission
- They discovered dramatic changes in performance, including residual image, bias offsets, gain changes, etc. and abandoned the Teledyne option